Electronics
Laser work
Medical diathermy and experimental cancer work
Welding
radar mechanics
Avionics workers
telecommunications workers

Rubber Products Workers
drying latex foams
gelling latex foams
preheating prior to curing and moulding

Textile Workers
Drying continuous webs
drying coated or impregnated yarns
drying rayon
drying wound packages
drying slasher coatings [9]

It is most often the operative and kindred workers who receive the highest exposures.

One proposal seriously being discussed in the current review of the Australian Standard is to raise the occupational limits by 10. It is these workers whose exposures could significantly increase if the permissible dose increases by 10 times the existing limits. If the way of measuring the radiation changes as is also proposed they would be less likely to be able to record their exposures or understand what is happening.

The NIOSH paper on the Known Biological Effects from Electromagnetic Radiation Exposures [9] are listed as follows:

Death
Genetic Effects
Teratogenic Effects
Behavioural Effects
Cataract

Acoustic response
Nervous system disorder
Headache
Blood level changes
Loss of memory
Dullness
Sleepiness
Sinus Arrhymias

There is also evidence that cancers, specifically of the brain,[11] and all leukemias, [12]are increased in persons who are occupationally exposed to these wavelengths, as well as among those exposed to ELF. In many electrical and electronics occupations exposures are to many different electromagnetic frequencies.

THE PUBLIC TRUST

Radiofrequency radiation standards are controversial and do not enjoy the public's confidence. Massachusetts Institute of Technology historian Professor Michael Stenick has researched the whole history of radiofrequency standards to discover why and how this profound lack of public confidence came to pass. In his book *The Microwave Debate [13]* Stenick documents the control exercised over paradigm generation and reinforcement by control over the funding of research. Stenick also shows an extraordinary level of direction was exercised by a tiny handful of specific individuals who were in charge of running the main research funding program, the US military's Tri Services Program throughout the 1950's.

Stenick records how the radiofrequency radiation standards were increased from an original industrial safety level of 100 $\mu W/cm^2$ (0.1 mW/cm^2) up to 10,000$\mu W/cm^2$ (10mW/cm^2). This was accomplished by the creation of a paradigm which stated that the only hazardous exposures to radiofrequency radiation are those resulting in thermal effects (tissue heating effects). As burns could be caused at 100 mW/cm^2 it was thought safe to expose humans at 1/10 of that level, 10mW/cm^2 [14] This limit of 10 mW/cm2 was accepted as being so unsafe as to be fatal in the early 1980's in a precedent setting compensation claims against the New York Telephone Company [15]

That there are thermal effects is universally accepted and the US and Western Alliance countries have adopted standards based on this paradigm.

As far as the hazards of radiofrequency radiation are concerned, there is, however, another paradigm, that changes in the endocrine and nervous systems mark the threshold of what should be considered to be deleterious exposures for humans. This has been described as the non- thermal school of thought.

There have been thus been two schools of thought about how to protect humans. It has been assumed that the research backing the non-thermal school was only conducted in the Soviet Union but considerable research into low level non-thermal effects was also conducted in the US as the Americans grappled with the meaning and intention of the low intensity non-thermal microwave irradiation, by the Soviets, of their embassy and staff in Moscow. [16]

Much of this American work looking at low intensity non-thermal effects was carried out in secret while the various possible military and intelligence scenarios for anti-personnel (death ray) and behaviour and mind control weapons applications of radiofrequency beams were explored. [17] [18]

It was the findings of this program of research in the late 1960's that created an impetus in the US for a change in thinking about radiofrequency bioeffects, and to the eventual and considerable, downward revision of the US radiofrequency radiation exposure standards, in the early 1980's.

This research, also, and the secrecy surrounding much of it, created a credibility problem for thermally based radiofrequency radiation safety standards.

The US program of research into the possible effects of the low intensity non-thermal radiofrequency irradiation of embassy staff led to a much improved open research program and to an unprecedented translation of Soviet science and exchange and cooperation with Soviet scientists. If, in Australia, we take all of this work into account in the considerations of what is safe today we will be more likely to establish a consensus that is credible and protects everybody's interests. The community and workforce is protected as far as possible based on current concerns, and with very few exceptions the industry has room to move and expand.

Much of the work that was conducted in secret has since been released under FOI and it must be part of an informed consideration of the hazards of radiofrequency radiation.

BASIC PRINCIPLES

In considering the task of establishing radiation exposure standards for the general public and for those who will be occupationally exposed it must be accepted that the first priority is to protect the health and well-being of the men women and children who will be exposed in non occupational settings, as well as those men and women who will be exposed regularly, if not as a matter of course, on a daily basis.

One approach to this task is to look at all the human, animal and cell system research and, recognising its limitations, set limits for exposure below those levels reported as causing changes in normal healthy functioning or behaviour. This approach leads to debate, about what is a significant change and what inferences can be validly extended from findings in animal and cell studies to human health.

Given the recognition earlier this century of the carcinogenic properties of many parts of the electromagnetic spectrum, in principle it should not surprise us that exposures to these forms of radiation are associated with an increased risk of the same forms of cancer and we should not spend fruitless hours vehemently denying even the possibility.

In principle if there is evidence of deleterious health effects, such as cancer-causing or promoting effects in animals then the radiation should be a presumed to be deleterious to humans. The level of probability that this is true increases if there is additional human evidence, such as increased rates of cancers among those exposed to these forms of radiation.

When standards are reviewed in the light of new evidence which reveals changes in the acceptable levels of risk and exposure limits are consequently modified, there are going to be some electromagnetic applications that will be effected. If the limits are reduced some changes in industry practise will have to be made some equipment will have to be modified, greater safety buffer zones established. The cost of these changes will have to be borne and cannot be used as a reason for compromising on the health of the population.

As a matter of principle it should not be the concern of those involved in setting standards to protect the current operational and financial interests of those who would have to make changes to protect employees and the public health.

People will want to know what is safe and many will look for a straightforward and simple answer. Engineers will design to the parameters established, lawyers will argue these are the existing standards so abiding by them assures that the general duty of care is met.

But "Safe" is not and cannot be an absolute term. We are working in areas where everything is far from being certain and already known.

A growing body of public opinion has little faith in the standards that have been set in the past or in the process that gave rise to them.

When there is uncertainty about the levels and frequencies associated with increased health risks, who should have the benefit of the doubt? The principle must be firmly established that it is those whose health may be affected should be afforded protection, not those who have a franchise on parts of the radiofrequency spectrum.

IS THE COMMITTEE CHARGED WITH REVIEWING THE AUSTRALIAN STANDARDS REPRESENTATIVE?

" risk management is fundamentally a question of values.
In a democratic society there is no acceptable way to make these choices without
involving the citizens who will be affected by them" [19]

The committee in Australia has been dominated numerically by the spectrum users, specifically the military, government utilities and some of the commercial interests. The process of setting radiation exposure standards is seen to be unrepresentative and exclusive, not only in terms of the interests represented but also in the areas of expertise. There are no true community organisations represented, there are no

biologists or medical experts who are not closely associated with a spectrum user to provide input in areas where empirical research into bioeffects has been conducted.

The military has a justifiable need to be involved, given the military uses of these forms of radiation and the ways military radiofrequency systems may impinge on the general community as well on military personnel It is recognised that the defence implications of radar and other electromagnetic systems will lead to a relatively closed way of dealing with issues of radiofrequency radiation and health. In time of military conflict it is acknowledged that the issues of possible health effects at low levels are very much secondary issues in the hierarchy of concerns.

While the military obviously does not wish to harm its own people, the military culture does operate with a different set of expectations about what constitutes acceptable levels of risk. However just because higher levels of risk are accepted on joining the forces, does not justify these levels being imposed on the general community or in the civilian workforce.

There needs to be more representation of the community interests on the sub-committee and a way found to separate civilian and essential military and defence needs.

As a general principle, then, it may be necessary to separate out military uses that are vital for the nation's defence and treat them separately rather than attempt to argue that the high exposure levels incurred in these facilities are safe for everyone.

NON OCCUPATIONAL EXPOSURE LIMITS

As matters now stand the levels of exposure to radiofrequency and radiofrequency radiation for the vast majority in the general community are very low, with the existing standard allowing for significant increases from that base, for all the people.

A common relationship between occupational exposure standards and non occupational standards is that non occupational standards should be set at one tenth of the occupational limits. The rationale for this is that workers are exposed for a shorter time and are generally more healthy than the entire community which includes pregnant

women, young children, sick and elderly people. Furthermore the general population can be exposed, unwittingly, for all 24 hours, each day.

The existing general population electromagnetic exposure limits were set at one fifth of the occupational limits to minimise the difficulties that certain sectors of the broadcasting industry would have had in their localities had the standard followed the usual relationship.

This may be very convenient for the industry concerned but is unjustifiable if there is any evidence of bioeffects at these levels. This needs to be well considered during this review and was highlighted as a failing in the first Australian standard by CSIRO's Dr David Hollway.[20]

There appears to be a reluctance to accept that the actual levels of RF exposure for the general population are generally very low, given that this reflects well on the responsible, planning and design that characterises most broadcasting sites and radiofrequency telecommunications applications. In the mid 1980's, when the current limits were set, the industry would have had to spend some money to conform with a lower limit but chose to save itself the money and trouble by forcing through a non-occupational limit double that proposed.

Since the standard was first promulgated it is quite likely that new housing developments have placed more people inside the buffer zones that would and should have remained unoccupied if the non occupational limit had been kept at 1\10th of the occupational limits.

A BROAD OVERVIEW OF THE BIOLOGICAL AND HEALTH EFFECTS OF ELECTROMAGNETIC FIELDS

A significant body of literature has been accumulating since the late 1970's that associates occupational and general public exposures to electrical and magnetic fields with significantly increased risks of certain cancers. This work has tended to focus on the magnetic fields associated with electrical power frequencies but there is also evidence of increased cancer rates in populations exposed to radiation in the kilohertz to Gigahertz range.[21, 22, 23,24, 25]

In radio and electronics work occupational exposures that encompass ELF and radiofrequencys are common. The electromagnetic radiation exposures in the workplace and in the general community don't fit neatly into wavebands but are broad and intermeshed.

The cancers significantly associated with occupational and general population exposure to electromagnetic radiation are those affecting the brain and nervous system, all leukemias, and most recently cancer of the breast.[26 - 50]

In the pages that follow observations of effects, at non-thermal and thermal levels of exposure on the brain and nervous system, the blood forming system and the endocrine system are reported.

THE IRRADIATION OF THE US EMBASSY IN MOSCOW

The public wariness of claims about the adequacy of safety standards for radiofrequency radiation has its roots in the infamous and prolonged episode in Moscow where the Soviet Union ran a program of regularly irradiating the American Embassy and all its staff.

By establishing a monitoring program of the irradiation the State Department analysed the power, frequency and modulation of the signal. This monitoring established that the signal was a modulated low intensity radiation and that the frequencies used to irradiate the US Embassy were in the "S" and "L" bands (GHz).

In documents released under FOI it is stated that the levels of modulated radiofrequency irradiation were measured and ranged over 0.2 to 2 μW/cm2 with a highest peak of 5 μW/cm2. [51]
The US radiofrequency safe exposure standard at the time was 10000 μW/cm2 so these were relatively minuscule levels of radiation.

The irradiation of the US Embassy and staff in Moscow at levels far below those considered to be hazardous in the USA nevertheless led to a Presidential directive that *"intensive investigative research be conducted within the State Department, CIA and Department of Defence to determine what the threat is."* [52] Dr Sam Koslov a physicist at the Advanced Research Projects Agency was placed in charge of the

research program. Dr Kosiov was familiar with Soviet research findings postulated *"the signal was an attempt to produce a relatively low neurophysiological condition among embassy personnel" [53]*
Soviet literature of the time reported loss of memory, loss of concentration, fatigue and debilitation among human populations exposed to non-thermal levels of radiofrequency radiation and to investigate these effects part of the program that was set up included assessments of behaviour and performance effects.

This research looked at:

1. Discrimination Visual and Auditory Thresholds
2. Reaction Times : Avoidance
3. Vigilance Performance
4. Attention Span
5. Dynamic Muscular Strength
6. Critical Flicker Fusion

Another part of the research program was extensive medical testing of the Embassy staff including examinations for any genetic changes. This search for genetic damage was concealed from the embassy staff themselves and was conducted in secret using an elaborate subterfuge but when the actual area and scope of the program leaked out amidst rumours of findings of genetic damage this had the effect of causing very deep resentment, widespread suspicion and doubts about the credibility of official pronouncements about the safety of radiofrequency radiation.

EFFECTS ON THE BRAIN USING PRIMATES

In 1959 behavioural and central nervous system effects were described by Bach [13], a researcher at the US Institute for Neurological Diseases who irradiated the heads of rhesus monkeys at non-thermal levels in a tightly designed research program. When exposed the animals went through cyclical periods of drowsiness and arousal. During the drowsy periods they stared with a fixed stare and were "unresponsive to touch pain light and sometimes to sound stimuli". They then moved into a period of arousal characterised by rapid side to side head movements.

"By alternately switching the transmitter on and off one of these animals was brought to the point of successive arousal and complete relaxation in a 20 second cycle, reacting like a puppet on a string" [54]

Convulsions could be induced and death brought about in as short a time as 2 minutes 55 seconds.

The program of research used primates to get as close to human beings as possible and checked for changes in behaviour during tiny levels of radiofrequency exposure. The findings of research into behavioural effects on primates at exposure levels of 0.2 - 5 μW/cm2 and generally less than 1 mW /cm2 showed no effects. This is important and generally encouraging for the levels in the current Australian Standard which is 1mW/cm2 at these frequencies. Certainly no increase for workers to 10 mW/cm2 and the general population to 2mW/cm2 should be considered.

The Advanced Research Projects Agency however found that radiofrequency radiation in the GHz range was capable of inducing profound effects on behaviour in primates at levels of exposure to modulated fields of between 1 mW/cm2 and 5 mW/cm2

ARPA documents released under FOI report;

"The monkeys exposed to the specific synthetic Moscow signal in field strengths from 1 mW/cm^2 to 4.6 mW/cm^2 showed degradation of work performance after 10 hours-a-day exposure from 11 days to 21 days. This degradation in performance may be regarded as a vigilance function degradation. The effects appear to be grossly functional reversible. There is some evidence that repeated series of exposures sensitises the animal and shortens the latent period before signs of vigilance degradation appear" [55]

In other experiments conducted at 5 mW/cm^2 exposure the monkey which normally worked for 10 hours a day every day was observed to slow down and then ceased all work and went into a deep sleep similar to a coma.

"There is no question that penetration of the central nervous system has been achieved either directly or indirectly into that portion of the brain concerned with the changes in the work functions".

Events leading to these breakdowns were as follows. On the 12 th day of radiation a definite slowdown was recorded in the monkeys ability to time his work functions. On the 13th day of radiation the monkey further degraded and finally stopped working. For the next two days of radiation the monkeys condition remained unchanged- complete stoppage at which time the radiation was terminated. Three days later without radiation the monkey returned to normal operation in his work functions. For five additional days without radiation the monkey maintained a normal work pattern. Radiation was turned on after this period and after eight days of radiation slowdown in work functions was again recorded. On the 10the day of radiation complete stoppage occurred. The stoppage continued for the next three days at which time radiation was terminated. The next two days of recordings up to 15/12/1966, reveal the monkey had not returned to normal".

The ARPA report goes on to recommend:

"The US radiofrequency radiation standard safety standards should be overhauled to take account of the non-thermal damage potential.
The potential of exerting a degree of control on human behaviour by low level radiofrequency radiation must be carefully investigated." [56]

In later reports of experiments conducted in 1967 it is reported that

"for the record it should be noted that all of the positive findings were achieved at one half an order of magnitude below the accepted US standard for safe exposure" [56a]

That is at a level of 5 mW/cm^2.

It is worth noting that while work cessation is acknowledged as the most sensitive indicator in the papers provided to the review committee by the chairman who is supporting an increase to 10 mW/cm2 the actual levels of 5mW/cm2 causing these effects are not acknowledged in the paper provided.[56b]

It is instructive to review what happened to the US radiofrequency standard in the years following these secret programs of research because the impetus to reduce the standard began with the findings in these investigations. Programs of investigation were established in diverse areas of government. Throughout the 1970's a Program For Control of the Electromagnetic Pollution of the Environment was established in the

in the Department of Commerce, and in 1978 the Comptroller General issued a report entitled " More Protection from Radiofrequency Radiation Hazards Needed "[57]

It is necessary in the current review of the Australian standard, and especially where there are proposals to increase the exposure limits for workers from 1mW/cm2 to 10 mW/cm^2, to carefully consider this work and to firmly reject any proposal to allow humans to be exposed at such levels.

The policy processes that followed the ARPA work in the US, led to more open research and a program of cooperation with the Soviet Union and other Eastern European countries, and with this there came a more public and open acknowledgment of at least the possibility of risks to health at levels below thermal effects.

RUSSIAN RESEARCH FINDINGS

It is possible that scientists in the former Soviet Union actually knew more about the biological effects of radio frequency radiation earlier than their western counterparts. Certainly it had been a field of intensive study for all of the 20th century in Russia.

V Y Danilevskiy conducted the first experimental investigations of the biological effects of radio waves in Russia in 1900.[58]
The biological role of electromagnetic radiations was first comprehensively defined in 1926 by V I Vernadskiy[59], a member of the Soviet Academy of Science and from there investigative work continued through the 1930's, 40's 50's and 60's mainly focusing on three areas:

1. The thermal effects of radio waves
2. The specific action of these waves on the organism which were discernible apart from heating effects. These are what the Russians called the non-thermal effects.
3. The radio frequency emission from the human brain

In 1930 Patzold [60] established that the thermal effect depended on the conductivity of diaelectric solutions and that different electrolytes heated differently. Patzold derived a formula that can be used to find the conductivity at which maximum heating

is obtained and plotted a diagram of the wavelengths that produce the most distinct thermal effects in the rabbit and other experimental animals.

Thus Patzold demonstrated wavelengths of 79cm for heating of cerebro spinal fluid, 93cm for bile, 177cm for blood, 7m 87 cm for the brain and so forth and this work was replicated and extended by others throughout the 1930's. The purpose of studies of Patzold and others was to learn about tissue heating as a function of tissue conductivity and dielectric constant. It was discovered that there were different depths of penetration and heating effects in skin, in fat and in muscle tissues and that there was a layered effect which increased the heating effect. But they were unable to explain the diversity of the biological effects in structures under exposure to radiofrequency waves.

Systematic research into the thermal effects of radiofrequency waves continued through the post war years. In 1963 Mirutenko [61]] showed that heating of certain tissues was observable at 10 mW/cm^2 reinforcing Deichmann's experiments of 1961 [62] which demonstrated that absorption of electromagnetic waves of 12.4cm at 10 mW/cm^2 caused an excess amount of heat in the organism.

Deichmann concluded that the Maximum Permissible Levels adopted at that time in the USA of 10 mW/cm^2 with no limit on time of exposure was too high.
In the early 1960's Soviet scientists carried out numerous experiments at 10 mW/cm^2 which convinced them that 10 mW/cm^2 was unsafe for humans. [63]

EFFECTS ON THE BRAIN

Among electronics workers exposed to microwaves and radiofrequency waves and among electrical workers a statistically significant increase in the incidence of brain tumour, particularly of the glioma and astrocytoma types, has been reported. The risk of this cancer increases with increasing exposure time [64] . It is therefore essential that we pay attention to all of the literature on electromagnetic radiation effects on the brain and particularly to any research showing changes or damage in the glial cells.

Russian research has paid particular attention to the brain and nervous system and has reported a singular sensitivity in the glial cells.

The most distinct changes in the nervous system during exposure at low intensities are observed in the conditioned reflex activity of animals. Changes in motor conditioning reflexes were frequently observed in rats irradiated with radiofrequencys (10cm wavelength 10 mW/cm^2 for one hour a day).
The latent time of the reactions first became shorter and then longer after the 15 - 17th treatment stronger suppression of the reflex was noted and sometimes even disappearance of the reflexes occurred. Under almost identical experimental conditions (wavelength 12.6 cm at 10 mW/cm^2) extinction of conditioned reflexes took place three times as fast in irradiated animals as in control animals.

The conditioned reflexes of rats exposed to decimeter waves were suppressed with a few treatments of exposure for 1 hour a day and recovery of normal cerebral cortex activity took two months to re-establish after all exposures had been discontinued..
Histological examination of the brains of rats exposed to 3cm waves at 10 mW/cm^2 showed distinct changes in the interneuron axodedral and axosomatic connections in the cortex. In particular there were changes in the synaptic apparatus of the cortical pyramidal cells.[65].

There were distinct shifts in the neuroglia: the number of astrocytes had increased. The Russians advanced the view in 1967

"that the brain and its glial cells in particular have a receptor function with respect to electromagnetic fields". [66]

This is of considerable importance given :

a) the recognition of a steadily increasing rate of glioma (brain tumour) as a statistically significant cause of increased mortality
b) the recognition of glioma as a particular cancer occurring in a statistically significant number of cases especially in electrical and electronics workers. A four fold increase in Glioma has also recently been reported in women VDU operators where exposure to VLF and ELF occurs. [67]

Of all the cancers reported among workers exposed to electrical and magnetic fields Glioma is the most strongly associated with occupational exposures to

Electromagnetic Fields and it shows a clear dose response curve of increasing incidence with longer periods of time in the exposed occupations.

In the Russian text The Effect of Electromagnetic and Magnetic Fields on the Central Nervous System, Kholodov reports;

> *In recording the electrical brain reactions to different electromagnetic fields we noted the appearance of slow high amplitude oscillations of potentials. In recent years certain investigators have attributed the main role in the formation of slow components of the EEG to glial elements. Recording the electrical activity in the region of the medulla oblongata which basically contains glial cells revealed a rhythm of 3-6 Hz and superslow oscillations... Finally morphological investigations of the brain following an animals stay in different electromagnetic fields indicated a glial reaction to these influences. We noted a revived proliferation reaction of the microglia in the brain following exposure of the animals to an SHF field of average 40 mW/cm^2 and at low 10mW/cm2 intensities which indicated the stimulating effect of an SHF field.*
> *Swelling of separate cells was observed at the same time. A protective reaction of the glial was frequently more explicit following a 5 minute exposure to an SHF field than after a fifteen minute exposure. These changes in the glial cells are considered to be nonspecific protective reaction of the central nervous system. Morphologists long ago noted the reaction of the glia following exposure to ionising radiation while neurons remained normal. Studying the morphological structure of the brain from irradiated dogs L L Vaconikov in 1956 concluded that the glial tissue especially the astrocytes and the vascular system connected with it suffers primary damage during irradiation. Especially acute degeneration of astroglia was observed in the brain stem and in the region of the hypothalamus.*
>
> *In rabbits one hour after the start of the EMF influence we noted a sharp productive reaction of the astroglia and oligodendroglia involving hyperplasia and hypertrophy of the cell bodies and processes. In rabbits and rats 10-12 hours after the start of the of the influence of EMF the reaction of the glia remained productive involving the presence of perivascular and marginal glial fibrosis, with changes in the oligodendroglia hypertrophy of the*

drainage cells. The neurons underwent reversible changes in the form of swelling.

In rabbits cats and rats 60 - 70 hours after the start of the EMF influence we observed productive-dystrophic damage to the microglia involving swelling of the oligodendocytes and appearance of drainage cells. A picture of dystrophic changes in the glia was morphologically diagnosed.

Since the glial formations are distinguished by a high metabolism we can consider that the effect of a EMF on the brain is realised to a significant degree through the changes in the metabolism of neuroglia.

Studying the experiments on the effects of an EMF on the CNS we can explain many of the results by the effect of an EMF on the glia. The last two series of experiments involving the recording of neuronal activity and a morphological analysis of the brain of rabbits subjected to a EMF directly implicates the glia in reactions to a EMF. In all our experiments we noted a prolonged latent period measured in seconds and tens of seconds. The long latent period indicates that neurons are not the primary elements reacting to the EMF since the latent period of their reaction is measured in milliseconds. A significant after effect also characterises the reaction of glial elements. [68]

NON-THERMAL EFFECTS

By the end of the 1930's the Russians had established there were specific non-thermal changes that appeared in the organism, that is changes that could not be explained solely in terms of heat formed in it. In 1936 Libezni [69] stated that the non-thermal effect of radio waves was the basic starting point and that the temperature rise in tissues merely masks the specific shifts in the organism.

In 1938 F M Suponitskaya [70] linked the influence of 40cm waves on the organism with nonthermal tissue changes which he ascribed to the vibrator effect on molecules.

The Russians found their own understanding of how radiofrequency radiation interacts with living organisms and their approach to the whole field of study was lacking integration and that the effects of radiofrequency radiation could only be successfully

understood, and their own research effort greatly improved, by bringing together a team of scientists representing various specialities; physics, radio electronics, physiology, pathophysiology, immunology, neuropathology, ophthalmology and physiotherapy.

By the second world war the Russians had recognised that workers operating radio electronics equipment were being adversely affected and that to solve the problems associated with their occupational exposures and to develop proper industrial hygiene controls the mechanisms by which radio waves act on biological objects had to be studied.

After WW2 the Russians began intensive investigations, using radiofrequency waves into the electrical properties of tissues and it was found that

> *"owing to the weaker absorption of radiofrequency energy by the fatty tissues less heat is liberated in the fatty layer than in the muscle. When the layered tissue system is irradiated therefore the temperature rise in the layer of muscle is larger than in the fatty layer even though the latter is nearer the source of the radiation." [71]*

Petrov notes that

> *" a marked temperature reaction of the organism to radiofrequency exposure is observed when the power flux density is more than 10 mW/cm^2. However organisms are also observed to react to the electromagnetic field at smaller radiofrequency power flux densities, even though the temperature rise is not observed. These phenomena belong in the category of non-thermal or specific effects of radiofrequencys".[72]*

As regards the central nervous system, the relatively thick bone texture of the skull and high lipid content of the brain tissues facilitate the penetration of radiofrequency radiation and interfere with the dissipation of heat into the environment. Also reflection and diffraction of radiofrequency radiation may take place within the spherically shaped skull; thus; in particular regions of the central nervous system radio frequency radiation could be more highly concentrated than would appear to be the case from incident power density. The reticular formation of the brain stem and the hypothalmus regions where important regulatory centres are located are areas most sensitive to electromagnetic radiation and even a small degree of hyperthermia in these regions might significantly disturb various body functions.

The role of the central nervous system is central to the way Russian scientists think about radiofrequency effects.

> *The CNS is the first system in animals irradiated at thermal intensities to undergo functional changes. (30 -40 mW/cm^2 for 20 minutes, wavelength 12.6 cm) Rabbits manifest abrupt suppression of conditioned reflex activity, and abrupt suppression of the basic rhythm of cerebral cortex electrical activity, dogs at 20 - 30 mW/cm^2 show a decrease in the strength of the conditioned reactions and an increase in their latent times. [73]*

A decrease in Cholinesterase activity in the cortex, cerebellum, brain stem and medulla oblongata and internal organs of rabbits during radiofrequency irradiation at sub-thermal levels (500 μW/cm^2) of rabbits was reported by Russian scientists in 1963. Petrov reports a series of experiments on cholinergic activity and states:

> *"Changes in the cholinergic link were established in these experiments on animals and on isolated muscle with radiofrequency irradiation. Apparently radiofrequencys may act as a stimulus that works through interoceptive links to change the cell membrane electrical potential or cause de or hyper polarisation. It is possible that entering the blood the acetylcholine formed in the synapses under radiofrequency exposure acts upon the chemoreceptors and pressoreceptors of the carotid sinus and on the skin-mechano and thermoreceptors causing reflex changes in the functions of the hypophysis and adrenal glands. Depending on the intensity of the rcdiofrequency exposure they cause either an enhancement and activation of cholinergic transfer in the irradiated object or a weakening of this process owing to disturbances in the formation of the attendant bio-chemical components with disturbance of the associated metabolism" [74]*

In the Russian studies of the effect of radiofrequency radiation on the permeability of cell membranes the threshold radiofrequency intensity leading to a significant change in the rates of ion transport across cell membranes following irradiation for two hours approximated 1 mW/cm2.

Electrophysiologic investigations of elementary excitable structures, like cell membranes, have been demonstrated at an extremely low intensity of radiation,
5 microwatts/cm^2. These investigations have revealed changes in a number of functional parameters and characteristics, namely, a slowed conduction of impulses, an increased synaptic delay, lengthening of latent and refractory periods, changes in action potential, (all in isolated nerve and muscle fibres of the frog) inhibition of impulse a contribution from the nonspecific subcortical and stem structures. This is particularly true of the hypothalamus where changes at low intensities 30 - 100 μW/cm^2 taking place in both acute and chronic experiments are of exceptional interest because the hypothalmus constitutes the structure connecting nervous and humoral means of regulation. Experimental investigations show that following radiofrequency irradiation the ascending activating influence of the reticular formation of the cortex is blocked."
Changes in the regulatory activities of the hypothalmic region due to radiofrequency irradiation of non thermogenic intensities also results in shifts in cholinergic processes participation of choline reactive and adrenergic structures of the brain as well as biphasic changes in vascular tonus with accompanying changes in accumulation of neurosecretion within nervous cells and tissues of the hypothalmus region.

At low intensities of the order of 1 mW/cm^2 radiofrequency induced disturbances of adaptation to various factors have also been observed. All the above findings taken together bring us closer to understanding the pathogenesis of the neurologic manifestations of radiofrequency sickness by showing clearly that in human beings the astheno-vegetative shifts and psychophysiological symptoms are mainly of a mesoencephalo-diencephalic nature and are elicited by radiofrequency of low intensity activity of single ganglionic neurons (the medicinal leech)"

CNS effects have been observed at intensities up to 1 mW/cm^2. These affects are determined by both a direct action on the brain and reflex component and intersystem relations within the brain. [75]

DIALOGUE BETWEEN WEST AND EAST

At the first International Conference between the Eastern bloc and the West which was held in Poland in 1973 Russian scientists mapped out the state of their knowledge and the various thresholds and conditions of exposure that they had empirically established.

Firstly, as far as exposure conditions are concerned, the Russians had initially used continuous exposures in their investigations but realised this was not an accurate representation of the real world and so tried in their experimental work to replicate the actual conditions people are exposed to in industrial conditions

> *"which are characterised by alternations in the periods of irradiation and intervals of various durations in combination with variability in the intensity of radiation, ie the radiation is intermittent in terms of a number of parameters". [76]*

Bychkov et al monitored the electrical activity in the brains of irradiated rabbits using 3GHz "employing an experimental method which adequately simulated industrial conditions. The animals were subjected to 150 $\mu W/cm^2$ for 8 minutes; 10 minutes rest; 60$\mu W/cm^2$ for 8 minutes; 240$\mu W/cm2$ for 6 minutes; 34 minutes rest; 320 $\mu W/cm2$ for 12 minutes 60 $\mu W/cm2$ for 8 minutes 14 minutes rest 60 $\mu W/cm2$ for 8 minutes 150 $\mu W/cm2$ for 8 minutes. The total time of actual irradiation was one hour. A parallel series of experiments was conducted with continuous radiation 153 $\mu W/cm2$ for 1 hour. In both series the incident energy as well as the total period of exposure were equal.

A non irradiated control group was also monitored.

> *The statistical data from the experiment show distinct although limited changes in the spontaneous electrical activity in the brains in the case of both series of (exposed) animals with statistically significant differences in changes evident in series 1 (intermittent exposure) after 10 exposures. [77]*

Gordon in summarising this and other work reported that

> *"intermittent exposure to irradiation results in more pronounced biologic effects than those of steady irradiation under conditions of equal strength and*

time parameters. One could hypothesise that intermittent exposure is much more strenuous for the adaptation and compensation mechanisms owing to the frequent changes in the irradiating parameters". .... Biological effects become more severe with increasing duration of work accompanied by irradiations of low intensities less than 1 mW/cm^2. [78]

This has both considerable implications for peak pulsed exposures and for the overall standard to be adopted for 8 hour working days. It certainly does not support an increase up to 10 mW/cm^2 for a working day.

Secondly the terms thermal and non-thermal were defined as follows;

Thermal effects are those biologic sequelae which are due to integral rise of temperature of the body and its separate parts during whole body or local irradiation. Thermal effects are those biologic sequelae which are due to integral rise and the result of uneven heating of microstructures of a heterogeneous biologic tissue and may occur in the absence of the integral thermal effect.
Finally non-thermal or extra thermal effects are due to conversion of electromagnetic energy within an object into another form of non-thermal energy (molecular resonance absorption photochemical reaction etc). [79]

Clear Thermal effects occur at exposures of 10 mW/cm^2 and above.

Weak Thermal Effects occur between 1 and 10 mW/cm^2

Non-thermal effects occur below 1 mW/cm^2

Gordon reports that;

1 mW/cm^2 is also significant from the medical point of view according to a number of indicators, and even at intensities that are extremely low, such as 500 - 250 μW/cm^2 certain biologic effects occur (bioelectric phenomena with resetting to a new level of activity of the brain systems, changes in immunobiologic resistance including definite pathologic effects (reproductive functions).

Our in vivo investigations have shown that activity of a whole range of enzymes in the tissues of irradiated animals including cholinesterase changes markedly at intensities down to 1 mW/cm^2 [80]

In Russia clinical observations of men working in radiofrequency radiation exposures over many years led to the recognition of a distinct form of occupational disease marked by changes in the nervous and cardiovascular systems. Investigative work progressed both with experimental animals and cell systems and with exposed workers to try to learn more about the interactions between radiofrequency waves and biological systems.

Czerski reported on experiments on a series of experiments in which groups of rabbits guinea pigs and mice were exposed respectively to a pulsed field (2950MHz 1200 pulse at one microsecond) or to CW at 3 mW/cm^2 2 hours daily for a total of 74 or 158 hours. These experiments measured the rates of iron uptake into red blood cells, the rates of cell division in the bone marrow, and quantifying reactions of the lymphyocytic system.

As far as the iron metabolism results were concerned there were significant differences between irradiated and non irradiated control group and perhaps the most interesting finding is that 74 hours of exposure to pulsed radiofrequencys induced much more pronounced effects than exposure to CW of the same duration, the differences between these groups being highly significant. On the other hand 158 hours of exposure to CW radiofrequencys induced very similar effects to those of exposure to pulsed radiofrequencys of half that duration..

On the effects on the lymphocytic system which is of interest given the increased incidence of leukemias among humans occupationally exposed to electromagnetic waves

low dose irradiated rabbits undergo spontaneous lymphoblastoid transformation when cultured in vitro ..... these observations seem to indicate a peculiar susceptibility of the lymphocytes and lymphocytic system to radiofrequency radiation [81]

French researchers reported *" from clinical and biological investigations of people exposed to radiofrequencys we found that an exposure for a long time at a low mean power density 0.1 -0.2 mW/cm^2 produced subjective and objective disorders in a number of subjects."* [82] Using mice rats and rabbits and control non irradiated animals of the same strains the investigators irradiated the experimental animals at a mean of 2 mW/cm^2, frequency 3.105 MHz for 145 hours continuously and then sacrificed the animals and compared their internal organs

They reported the following:

SPLEEN

There was a greater extension of germinative centers in exposed animals than in controls; the cellular density increased and lymphoblastic cells were more numerous, in lymphoid areas the lymphocytes were abnormally distributed in sheets foci of eosinophil cells and large numbers of reticular cells were found .... Disorganisation of the hepatocytic structure and enlargement of the haematopoietic islet were also observed.

LIVER

An increase of the reticular and histocytic cells of mesenchymatic origin in the Disse spaces was noticed

THYMUS

The cellular density of the cortical areas was marked in the subcapsular zones by a great number of lymphoblasts [83]

These findings assist us in understanding why there is an excess of leukemias among workers exposed to electromagnetic fields

ENDOCRINE GLANDS.

Petrov reports that the functions of the anterior pituitary and adrenal cortex are regulated by the central nervous system and goes on to describe Russian work on the effects of radiofrequency radiation at thermal and non-thermal intensities on the

function of the pituitary and adrenal cortex, the thyroid gland and sex glands. Thermal intensities were found to suppress the hormone producing functions of the anterior pituitary and adrenals while non-thermal intensities enhanced them.
Various researchers report that dogs irradiated showed enhanced thyroid function with increased uptake of iodine. The power flux densities reported as causing this effect start at 3 mW/cm^2 for 30 minutes.

SEX GLAND FUNCTION AND REPRODUCTION

Animal male testicles that were exposed to 12.5cm waves for 5 - 15 seconds at 250 mW/cm^2 showed haemorrhaging, coagulation necrosis of the epithelium of the interstitial tissue and vessel walls although only a small temperature rise had been observed in the testes.
Similarly brief irradiation at 400 mW/cm^2 produced sterility.
A reduction in the size of the testes as compared to control animals was observed 29 days later.

Female animals that were irradiated were less fertile than controls and the offspring were born small and many of them perished during the first two days.

Imig et al in 1948 conducted a series of studies to determine the possible effects of radiofrequency waves on the male reproductive system. They reported;

> *The outcome of this experiment clearly shows that testicular damage from 12cm irradiations of a temperature below that of the abdominal cavity and below that necessary to cause injury by infra red exposure...damages may result in part from factors other than heat. [84]*

In the testes a high rate of cell division and differentiation is maintained in the seminal tubules. However the germ cells could easily be damaged by elevated temperatures of the testes. In addition the interstitial cells (Leydig cells) produce less androgen when the internal temperature of the testes is raised as in the case of exposure to radiofrequency radiation. The hypofunction of the leydig cells could be a secondary disturbance due pituitary insufficiency in gonadotropin secretion under the influence of radiofrequency radiation; symptoms of pituitary hypofunction and functional disturbances of the pituitary-gonadal system have been observed in men and women exposed professionally to radiofrequency radiation.

REPRODUCTION

A study conducted at John Hopkins looking at the possible causes of mongolism found a statistically significant association between paternal exposure to radiofrequency radiation in the radar frequencies and mongolism in the offspring.'[85]

THE EFFECTS OF LOW-POWER RADIOFREQUENCY RADIATION ON CELLS AND TISSUES

The literature concerned with empirical studies of the effects of low power (athermal) radiofrequency radiation on cells and tissues has grown considerably but the lack of an agreed theoretical basis for the observed effects has discouraged official acceptance of their significance. This official disinterest is based in the fact that electromagnetic radiation with photon energies < 12 eV (i.e. of wavelengths longer than ultraviolet) were not sufficiently energetic to cause ionisation. Damage to cells and tissues by ionising radiation was well understood and, because of the industrial, military and medical importance of ionising radiation, the study of its effects tended to dominate the field and to provide models for studies of other potentially-damaging agents during the rapid development in molecular biology over the last three decades. Nevertheless a number of significant papers were published in parallel with the early epidemiological and experimental animal studies. Several of these studies were with effects of radiofrequency fields on blood cells, as these were readily obtainable and, in conformity with the knowledge of the period, with the expectation that they would provide surrogates for other cells of the body. These are of some interest today because of the apparent increased risk of leukemias reported among radio hams and more widely among those exposed to electrical and magnetic fields.

Baranski working in vitro with rabbit blood observed increased permeability of erythrocyte cell membranes to haemoglobin

> *after irradiation at 1 mW/cm^2 during 60 minutes changes in potassium metabolism were the earliest observed disturbances in erythrocytes irradiated with radiofrequencys. After only 15 minutes of irradiation at 1 mW/cm^2 a significant increase in potassium concentration in the supernatant was noted. The values were still higher after longer lasting irradiation or after irradiation at 5 or 10 mW/cm^2.*